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Grand Challenges in Photonics: Route to Light

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Frontiers in Photonics is a multidisciplinary journal platform targeting high-impact research in the Photonics field at large. As we just commence the third decade of the 21st century, Photonics is becoming more and more a ubiquitous paradigm that sustains the development of a vast spectrum of disciplines. In a landscape so vast, I would like to convey, from my editorial corner, the trepidation and excitement in embracing the scientific mission of Frontiers in Photonics.

In defining what Photonics is, the risk is, undoubtedly, to be trivial and limited. Photonics defines the core science and technology of light in a very broad sense. While this field certainly has an affinity with the general field of optics, with an ancestral origin and very soft (sometimes non-tangible) boundaries, its definition in methods and purpose is relatively recent, and traditionally attributed to Pierre Aigrain (although literature suggests a complex historical genesis) (Balkanski and Lallemand, 1974; Krasnodębski, 2018).

Although the term "photon" became the qualifier of Einstein's quantum of light in the late 20 s (Lewis, 1926) (and there are accounts that show that the term was already used even before then (Kragh, 2014)), in its accepted definition, the epistemology of "Photonics" is fundamentally broader with a definition being "the science of the harnessing of light. Photonics encompasses the generation of light, the detection of light, the management of light through guidance, manipulation, and amplification, and most importantly, its utilization for the benefit of mankind," and it is directly associated with the invention and diffusion of the laser source (Schawlow and Townes, 1958; Maiman, 1960).

An identifiable trend in the transition between the 20th and the 21st century saw the expansion of Photonics breaking boundaries and cross-pollinating different subject fields. Hence, biophotonics, quantum optics, plasmonics, integrated photonics, optical communications, and terahertz, just to cite a few, represent research areas with sometimes largely distinct sets of established methodologies, theoretical and experimental settings, cohorts of researchers engaged, and, often, distinct research dissemination outlets.

The challenges in those domains, although connected, are indeed distinct. While plasmonics is at the forefront of the effort toward pushing device scaling extremely beyond the wavelength limit (Fernández-Domínguez et al., 2017), integrated photonics is merging with nonlinear optics and complexity in a quest for implementing several complex functionalities (e.g., neuromorphic computing (Burr, 2019), microcombs (Pasquazi et al., 2018), and embedding a large number of degrees of freedom in wavelength-constrained devices. In a further example, quantum optics faces an explosion of new challenges intersecting information technology, communication, imaging, and sensing, with a rising constellation of discoveries, and most importantly, scientific questions, wiping out the classical boundary between physics and engineering (Walmsley, 2015).

Beyond the vital importance of fundamental discoveries, Photonics is, by definition, an applied science. For example, applications in medicine and biology are potent social and economic motivators for developing photonic technologies. Historically speaking, from the invention of the optical microscope (Helden, 2010), medicine and biology underwent countless transformations related to the exploitation of light.

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Indeed, new solutions for clinical diagnosis and therapies are a central challenge in biophotonics (Li and Pu, 2019). Many countries recognize Photonics as pivotal in facing major economic and societal challenges, like the green economy, sustainable development, security, inclusive healthcare, inequality, and the digital society, and strive to gain leadership in the field (Light is in the air, 2017). Europe acknowledged Photonics as one of the Key Enabling Technologies (KETs) of the 21st century and a centerpiece at the core of social development (European Commission, 2020). Notably, the United Kingdom Photonics Leadership Group and the All-Party Parliamentary Group in Photonics and Quantum have in 2020 offered an organic analysis of the industry's dependence on photonics technology and a view about how photonics research will contribute to economic and industrial growth (Photonics Leadership Group, 2020).

The primary mission embraced by Frontiers in Photonics is then to act as a conductor between all those domains, recognizing that the *progress* of a field is the ultimate research output, above every single exceptional scientific finding. In this sense, high-impact photonic research is not solely based on the report of an extraordinary discovery but also in the way such a discovery ripples in the field, eliciting validation, replication, refinement, confutation, and application.

We designed the broad portfolio of publication types of Frontiers in Photonics to capture this diverse landscape and the established interconnection between domains, offering researchers agile means to reach out, connect to existing scientific work, and showcase successful research endeavors. In such an interdisciplinary field, we aim to define the journal by the quality and impact of its research questions. Frontiers' *Research Topics* collections, proposed and led by prominent researchers in the field, are a central example, focusing on creating a critical core of experts around a high-impact research topic. In fact, a primary global challenge for science to become "knowledge" is for papers to document transformative discoveries with sufficient detail and accuracy to become tools for other researchers and non-researchers. This effort is the core target of Frontiers in Photonics.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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